Atypical motion sensitivity characterized by larger receptive fields in autism spectrum disorder

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Background

· Atypical visual sensitivity in autism spectrum disorder (ASD) has been widely observed across studies (Simmons et al., 2009).

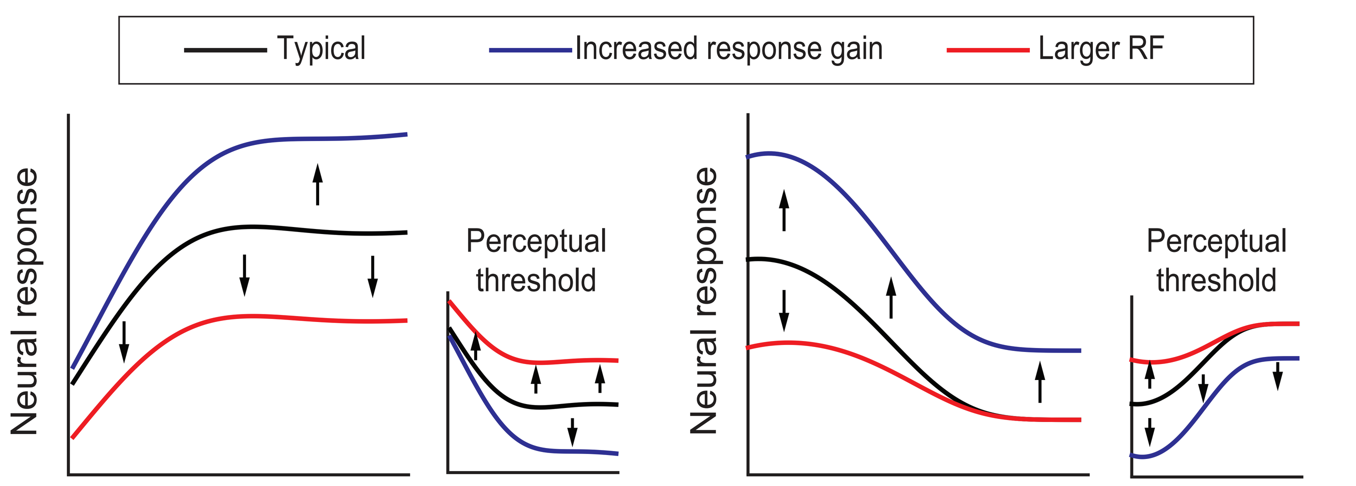
· Two emerging hypotheses underlying such atypicality:

1) Increased response gain

- Gain control: regulates neural response in relation to stimulus contrast
- Enhanced motion sensitivity has been observed in ASD with high, but not low contrast stimuli (Foss-Feig et al., 2013), suggesting a possible increase in response gain (Rosenberg et al., 2015).

2) Larger receptive field (RF) size

- RF size: modulates neural response in relation to stimulus size
- Larger population RF sizes have been observed in ASD (Schwarzkopft et al., 2014), but no perceptual correlate has been found



- Gain control: Typical neural response saturates at higher contrasts to prevent over-responding.
- Increased response gain leads to greater neural response at higher contrasts

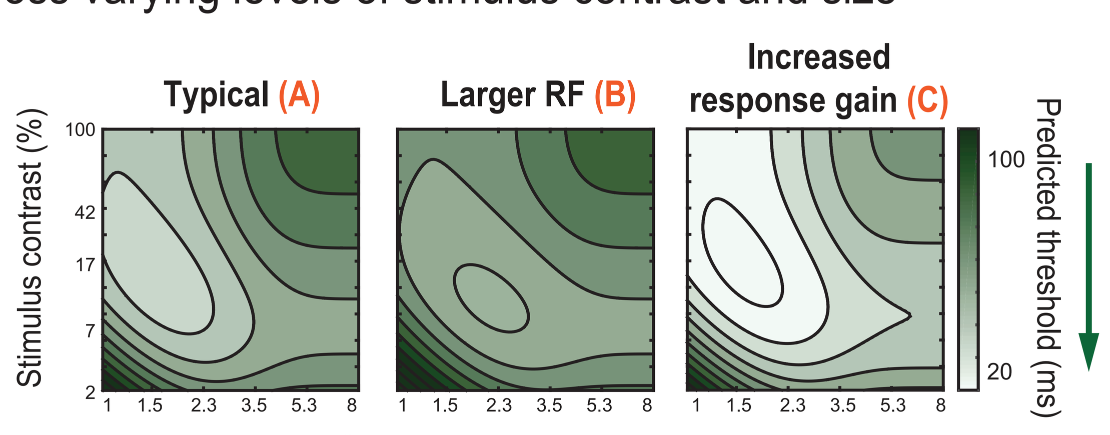
- RF: Typical neural response decreases with increasing stimulus size due to center-surround interactions in RF
- Larger RF leads to reduced neural response at smaller size

Present study

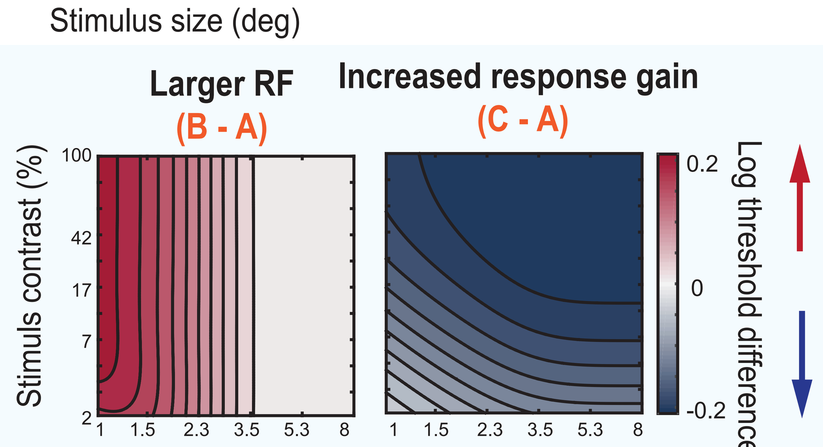
To investigate the integrity of gain control and RF size, and their effects on visual motion perception in ASD

Predictions

·The two hypotheses predict very distinct patterns in motion sensitivity across varying levels of stimulus contrast and size



Predicted Group Difference:

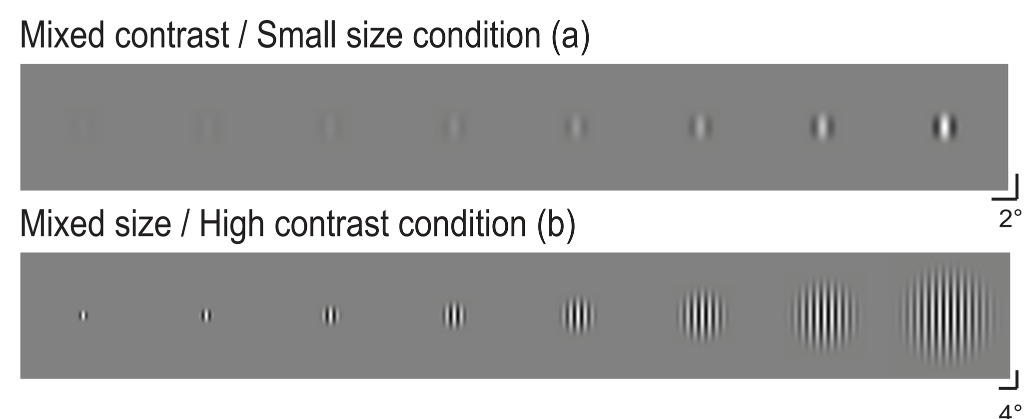


Psychophysical characterization of motion sensitivity in ASD

Measured motion discrimination thresholds across varying levels of stimulus contrast and size

Participants

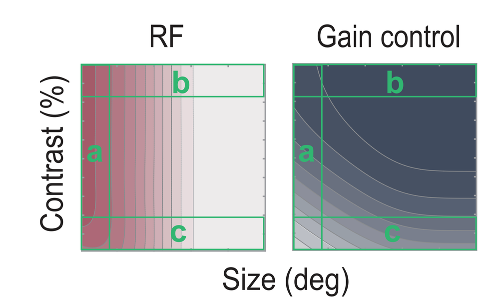
· 20 children and adolescents with ASD (mean age = 13.1 / IQ = 107.5)
· 20 tyically developing (TD) controls (mean age = 13.7 / IQ = 113.4)



Psychophysical Procedures

· **Contrast**: 2-99% / **Size**: 1-8° radius
· Task: Judging the direction of motion (left/right)
· Three conditions

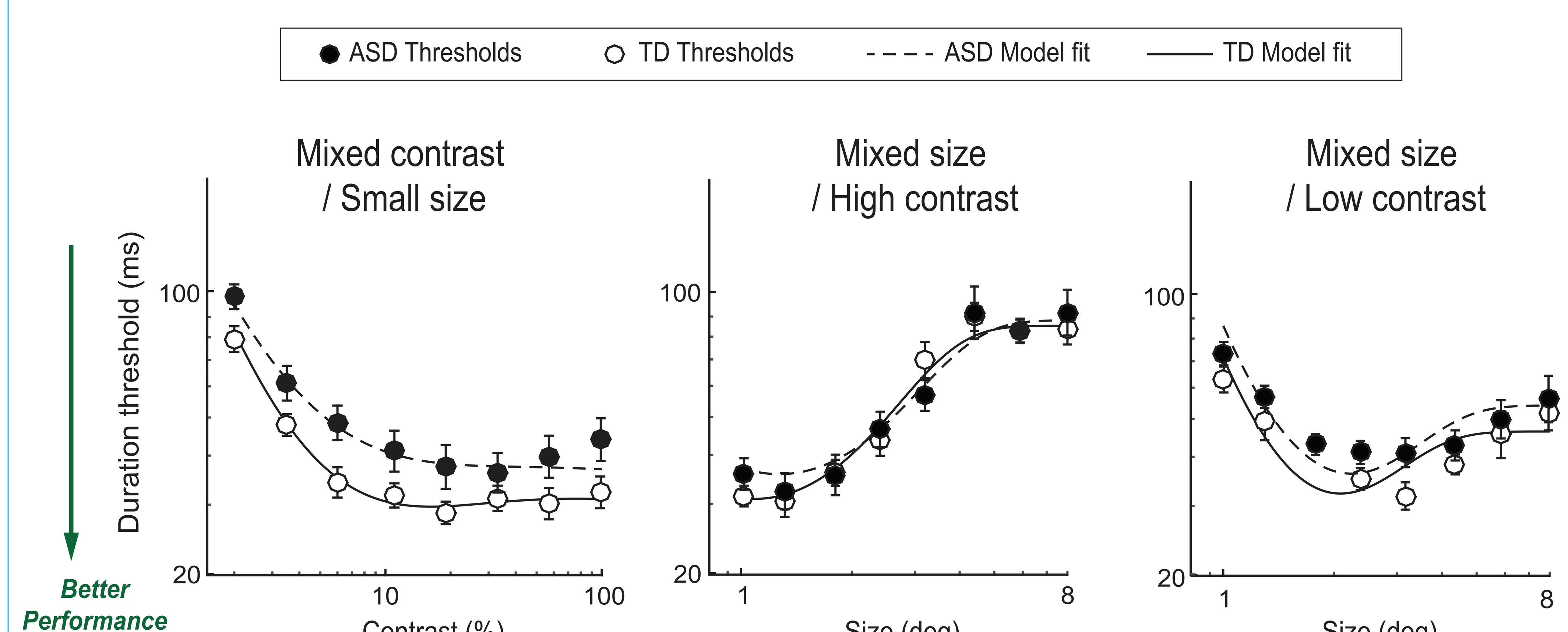
a: Mixed contrast / Small size
b: Mixed size / High contrast
c: Mixed size / Low contrast



· Measured duration thresholds (i.e., how long the stimuli were presented to reliably perceive directions)
· Stimulus presentation was controlled using an adaptive psychophysical technique (FAST toolbox; Vul et al., 2008)

Psychophysical Results

· Significantly worse performance in ASD was found across all contrast levels in the mixed-contrast/small-size condition ($F(1,38) = 5.49$, $p < 0.05$)
· No group differences were observed in either of the mixed-size conditions (p's > 0.05)
· This pattern of results is consistent with the *larger RF hypothesis*



Evaluation of gain and RF size in ASD

Fitted a model to estimated thresholds to assess mechanisms

· The model assumes a receptive field with an excitatory (*E*) center and an inhibitory (*I*) surround whose responses depend on the gain (*Ae, Ai*) and RF size (*α, β*), (Betts et al., 2012; Tadin et al., 2005).

$$E(w) = 1 - e^{-\frac{(w/\alpha)^2}{2}}$$

$$I(w) = 1 - e^{-\frac{(w/\beta)^2}{2}}$$

$$R(w,c) = \frac{K_e(c) \cdot E(w)}{1 + K_i(c) \cdot I(w)}$$

$$K_e(c) = A_e \frac{c^{n_e}}{c^{n_e} + c50_e^{n_e}}$$

$$T = \frac{Criterion}{R_0 + R}$$

$$K_i(c) = A_i \frac{c^{n_i}}{c^{n_i} + c50_i^{n_i}}$$

w: stimulus size
c: stimulus contrast
n_e, n_i: slope of contrast-response function
c_{50e}, c_{50i}: semi-saturation point
R: neural response
T: threshold.
Criterion, R_0: scales neural response to thresholds (fixed at 20, and 6, respecitvely)

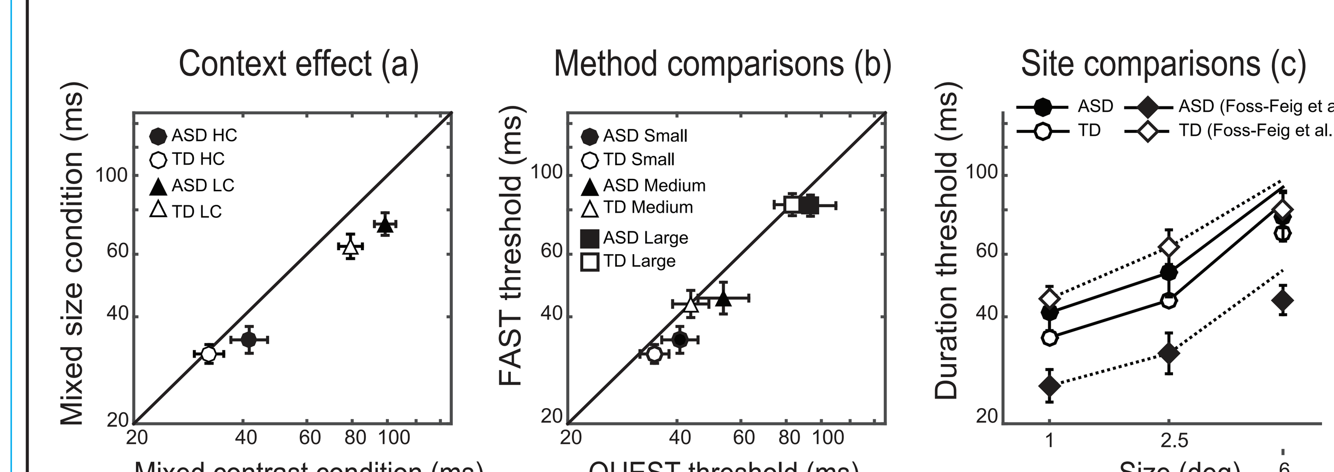
Model Results

· Significantly larger excitatory RF size was observed in ASD
· No group differences were found in the gain parameters

		A_e	A_i	α	β	C_{50e}	C_{50i}	n_e	n_i
ASD	Estimates	248.61	56.32	**1.32**	1.84	0.23	0.26	0.95	1.12
	95% CI	[242.68, 250.62]	[49.02, 67.91]	[1.19, 1.46]	[1.63, 2.05]	[0.13, 0.54]	[0.16, 0.72]	[0.74, 1.15]	[0.84, 1.35]
TD	Estimates	249.16	54.32	**1.2**	1.72				
	95% CI	[246.61, 253.56]	[48.2, 67.11]	[1.06, 1.33]	[1.54, 1.91]				
	p-values	0.42	0.26	**0.009**	0.12				

Supplemental Analyses

· Is performance in ASD different across task contexts (a)?
· Do methodological differences influcne performance in ASD (b)?
· How do our findings compare to previous findings (c)?



Conclusions

· ***Selective impairments in motion sensitivity*** in ASD at small stimulus size across all levels of contrast
· ***Larger RF size*** in ASD best explains such percepual difference
· Possible existence of subgroups in ASD in regards to motion perception
· Larger RF size may influence neural E/I balance in ASD by differentially disrupting neural response across stimulus contrast and size

References

Betts, L. R. et al., (2012). Vis Res, 53(1), 1–14.
Foss-Feig, J. et al., (2013). J Neurosci, 33(19), 8243–49.
Rosenberg, A., et al., (2015). PNAS, 112(30), 9158–65.
Schwarzkopf, D. S., et al., (2014). J Neurosci, 34(7), 2713–24.
Tadin, D., et al., (2005). Vis Res, 45(16), 2059–64.
Vul, E., et al., (2010). Seeing Perceiving, 23(5), 483–515.

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